The Predication of the Type of Jupiter Radio Storm from Two Different Iraqi Locations

Kamal M.Abood* ***Rasha H. Ibrahim****

Received 23,November,2011
Accepted 21,May,2012

Abstract:

A program in Visual Basic language was designed to predict the type of radio storm that emitted from Jupiter at specific Local Time (LT) from two different Iraqi locations (Baghdad and Basra), such storms result from the Central Meridian Longitude (CML) of system III for Jupiter and phase of Io's satellite (Φ_{Io}). Some of these storms are related to position of Io (Io- A,B,C,D) and others are unrelated (non-Io-A,B,C,D) to its position. The input parameters for this program were user specified by determining the observer's location (longitude), year, month and day. The output program results in form of tables provides the observer with information about the date and the LT of beginning and end of each type of emitted storm. Two Io-storm ranges were used in this program according to the standard observations, one of them at year 2008 and the other one at 1976, the results according to year 2008 gave the observer more types of storms as compared with results that depending on 1976, these results indicated the type of storm is not changed for these two locations, but their LT was changed, because it depend on the location of the observer. The obtained results reveal a good agreement as compared with the results of (**Radio Jove**) software.

Key words: Jupiter, Storms of Jupiter, Decametric Emission of Jupiter.

Introduction:

Jupiter is the most massive planet. In fact, it makes up 70% of all planetary matter in the solar system. It is also the largest planet; its diameter is approximately 11 times as large as the diameter of the Earth's, and 1/10 as large as the Sun's. Despite its huge size, and tremendous internal pressure, the density of Jupiter is only 1330 kg/m^3. Alternating dark belts and light zones lying parallel to its equator. The magnetic field at Jupiter is 14 times as strong as the magnetic field at the surface of the Earth [1]. It has three coordinates systems. System I, applies for regions near the equator with rotation period $9^h50^m30^s$, system II, applies for regions near the poles (far from the equator) with rotation period $9^h55^m41^s$, these two coordinates systems are related to the clouds motion, while system III related to the internal magnetic field of it with rotation period $9^h55^m29.71^s$, for each of these three systems has a CML [1,2]. The Decametric (DAM) radiations from Jupiter are so intense, affected by the rotational phase of it and the orbital phase of its innermost Galilean satellite Io, which defined as the motion of Io around Jupiter's planet. Jupiter, Io's satellite and the co-rotating plasma torus constitute a unique system by this emission [3,4]. This kind of radiations results from the acceleration of electrons from Jupiter by cones, along Io Flux Tube (IFT) and directed towards Io's satellite then accelerated another time from Io to Jupiter. During radiation four types of storms (A,B,C and D) are picked up at frequency 22.2 MHz [5,6].

*Department of Astronomy and Space, Collage of Science, University of Baghdad.

The Storms of Jupiter

The emission mechanism that determines the Φ_{Io} and CML_{III} does not depend only on the detailed emission process, but also on the propagation characteristics within the Jovian ionosphere and magnetosphere. The orbital phase controls in terms of an emission mechanism, that determines the radiation within a small range of angles with respect to the magnetic field direction, and the CML, with respect to Jupiter, from this the storms are determined, as shown in fig.(1) [3], when the probability of reception, as well as the overall energy of the signals received from Jupiter are higher than the average, there is a probability of existence of these storms [7]. All the radio signals from Jupiter are divided into two types "storm" and "non-storm" events. Each storm consists of Io-related and Io-unrelated (non-Io) component according to Io's position has a strong, weak or non-existence influence respectively [8], as shown in fig. (2) [9].

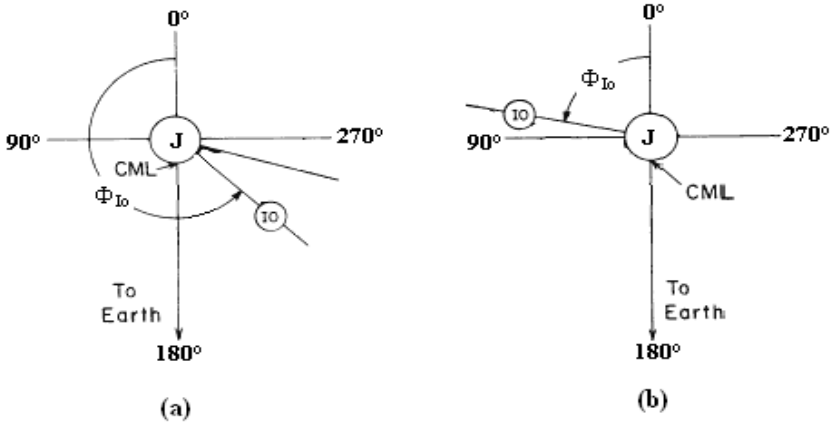


Fig.(1): (a): The phase of A (Φ_{Io-A}), (b): The phase of B (Φ_{Io-B}) [3].

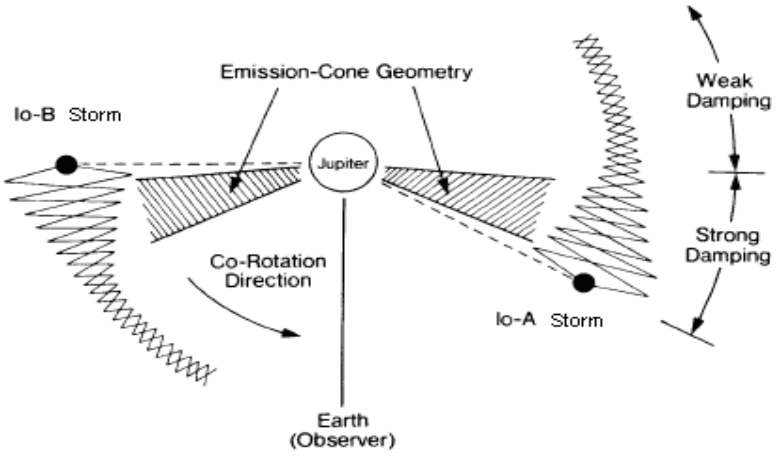


Fig. (2): Explains the strong and weak radiation are affected by the position of Io [9].

These storms are main (Io-A), early (Io-B), weak (Io-C) and fourth storm (Io-D) [6,10]. The Earth based observations showed that the exact location varies slowly depending on frequency, these observations from above Earth were continued by the spacecrafts, but the transition in CML_{III} and Φ_{Io} are limited by the interference in frequency and the speed of the spacecraft. The probability of observing (non-Io) from Nancy was shown to be high variable, and there are the same storm regions in Jovian magnetosphere. Data from the United Radio and Plasma Wave (URAPW) experiment were used to determine the angular size and the direction of the radio storms. The URAPW observations of Jovian radio radiations greatly improved the determination of storm locations [8]. The ranges of the storms that depend on the program to obtain the results of radio storms from Jupiter are given in tables (1) and (2) [7,8].

Table (1)
Ranges of storms according the year 1976 [7].

Type of Storm	CML (Degrees)	Φ_{Io} (Degrees)
Io-A	210 -270	220-260
Io-B	110 -190	65-105
Io-C	20-320	220-260

Table (2)
Ranges of storms according the year 2008 [8].

Type of Storm	CML (Degrees)	Φ_{Io} (Degrees)
Io-A	180 -300	180-260
Io-B	15-240	40-110
Io-C	60-280	200-260
Io-D	0-200	95-130
non-Io-A	200-300	0-360
non-Io-B	80-200	0-360
non-Io-C	300 -360	0-360
non-Io-D	0-200	0-360

Date and Time

It is often convenient in making astronomical calculations to use UT to deduce the LT in hours by [11]:

$$LT = UT + (\frac{\lambda_{City}}{15^\circ}) \ldots\ldots\ldots(1)$$

Where:
UT: is the universal time measured in hours, λ_{City}: is the longitude of the city measured in degrees (Baghdad=45°E and Basra=48°E). The CML_{III} and phase change for each instant so it is necessary to express them in terms of Julian Date (JD) and UT for each instant. The Julian Date can be defined, as the interval of time in days and fractions of a day since January 1st 4713 B.C.. That is midday, as measured on the Greenwich meridian [11]. The Julian date was calculated for all the year, which is specific case by equation [2]:

$$JD = INT[(365.25 \times (Y)] + 1721423.5 + B \ldots ..(2)$$

where:
B: is Gregorian calendar.
Y: is the year.

- The number of days is given by [2]:

$$d = JD - 2435108 \ldots\ldots\ldots\ldots(3)$$

Orbital Elements

The motion of the planets around the Sun and of the satellites around their planets, are controlled by the action of the gravity that is by mutual force of attraction between masses. Orbital elements are the parameters required to uniquely identify a specific orbit. In celestial mechanics these elements are generally considered in classical two body systems. The CML of Jupiter is change for each instant during the year,

which can be found from several astronomical elements [11].

- Argument (V_J) for the long - period term in the motion of Jupiter is given by [2]:

$$V_J = 157.0456 + 0.0011159d \quad \ldots\ldots\ldots\ldots (4)$$

- Mean anomaly for Earth (M_E), and Jupiter (N_J) is given by [2]:

$$M_E = 357.2148 + 0.9856003d \quad \ldots\ldots\ldots (5)$$

$$N_J = 94.3455 + 0.0830853d + 0.33\,Sin\,(V_J) \quad \ldots\ldots .. (6)$$

- Difference (J) between the mean heliocentric longitude of Earth and Jupiter by [2]:

$$J = 351.4266 + 0.9025179d + 0.33\,Sin\,(V_J) \quad \ldots\ldots\ldots (7)$$

Where:
V_J, M_E, N_J, and J are expressed in degrees.

- Equations of center of Earth (A_E), and Jupiter (B_J), they are also expressed in degrees, are given by [2]:

$$A_E = 1.916\ Sin\,(M_E) + 0.020\ Sin\,(2M_E) \quad \ldots\ldots (8)$$

$$B_J = 5.552\ Sin\,(N_J) + 0.167\ Sin\,(2N_J) \quad \ldots\ldots (9)$$

- And use another relation to link them as [2]:

$$K = J + A_E - B_J \quad \ldots\ldots\ldots\ldots (10)$$

- Radius vector for Earth (R_E) and Jupiter (R_J) are given by [2]:

$$R_E = 1.00014 - 0.01672\ Cos\,(M_E) - 0.00014 Cos\,(2M_E) \quad \ldots (11)$$

$$R_J = 5.20867 - 0.25192\,Cos\,(N_J) - 0.00610\,Cos\,(2N_J) \quad \ldots\ldots (12)$$

- Distance (Δ) from Earth to Jupiter by [2]:

$$\Delta = \sqrt{(R_J)^2 + (R_E)^2 - 2R_J R_E Cos\,(K)} \quad \ldots (13)$$

R_J, R_E, and Δ are expressed in Astronomical Units (AU), and the distance from Earth to Jupiter (Δ) always be positive.

- Phase angle of Jupiter (Ψ_J), which is the angle in phase with Jupiter with respect to the observer on the Earth is given by [2]:

$$Sin\ \Psi_J = \left(\frac{R_J}{\Delta}\right) Sin\,(K) \quad \ldots\ldots\ldots (14)$$

As mentioned, the CML, and phase are change for each instant, so the equations of CML of the tree systems (system I, II and III) of Jupiter are given by [11]:

$$CML_{I,II} = 150.4529\left(d - \frac{\Delta}{173}\right) + 870.4529\left(d - \frac{\Delta}{173}\right) \quad \ldots\ldots\ldots\ldots\ldots (15)$$

$$CML_{III} = 274.319 + \Psi_J - B_J + CML_{I,II} \quad \ldots\ldots\ldots\ldots\ldots (16)$$

Where:
$\frac{\Delta}{173}$: is the correction for the light time, expressed in days, and the denominator 173 results from the fact, that the light time for unit distance is 1/173 day. The CML of Jupiter should be reduced to the interval (0-360)°.

denominator 173 results from the fact, that the light time for unit distance is 1/173 day. The CML of Jupiter should be reduced to the interval (0-360)°.

- The angles of the Galilean satellites are measured from the inferior conjunction with Jupiter, so that U=0° corresponds to satellite's inferior conjunction, U=90° with its greatest western elongation, U=180° with the superior conjunction, and U=270° with the greatest western elongation the angles of Io's satellite are given by [2]:

$$U_1 = 101.5265 + 203.405863\,(d - \frac{\Delta}{173}) + \Psi_J - B_J \quad \ldots\ldots(17)$$

$$U_2 = 67.81114 + 101.291632\,(d - \frac{\Delta}{173}) + \Psi_J - B_J \quad \ldots\ldots(18)$$

- The equation of the phase is given by [2]:

$$\Phi_{Io} = 0.472\,\mathrm{Sin}\left[2\,(U_1 - U_2)\right] \quad \ldots\ldots(19)$$

Where: U1, U2 and Φ_{Io} should be reduced to the interval (0-360)°.

Programming Testing

A program in visual basic language was used and the equation that mentioned previously to predict the type of radio storms that emitted from Jupiter at specific LT by determining (the observer's location, year, month and day), the flowchart of the program that calculates the predicted storm was given in appendix, the observation at year 1976 and Baghdad location was chosen in our testing. The application window of the main program is shown in fig.3, which shows the occurrence probability of radio storm from Jupiter. The user can enter any year in text (YYYY), any month in text (MM), any day in text (DD), while the location was chosen by any commands for location, which are displayed in the main window. The results provide the observer information about the date of beginning and end of each type of predicated storm and their LT, these results indicated that the observer on Earth in some days can not receive any type of storm in date 10th of January 2011 and ask the user to input another day or month, while in other days he receives one type (Io-B) in date 1st of January 2011 or more than one type (Io-A) and (Io-C) in date 11th of January 2011, as shown in figs.4,5 and 6.

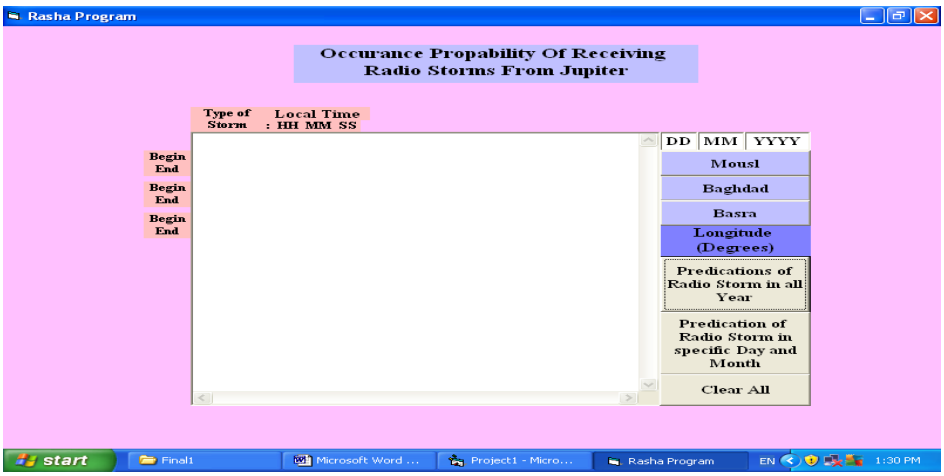


Fig.3: The application window of the main progam

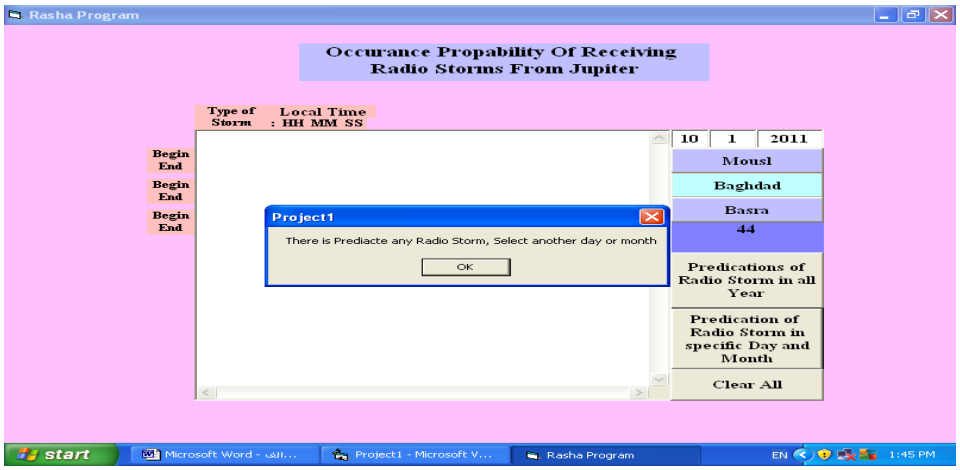


Fig.4: The application window explains there is program no radio storm

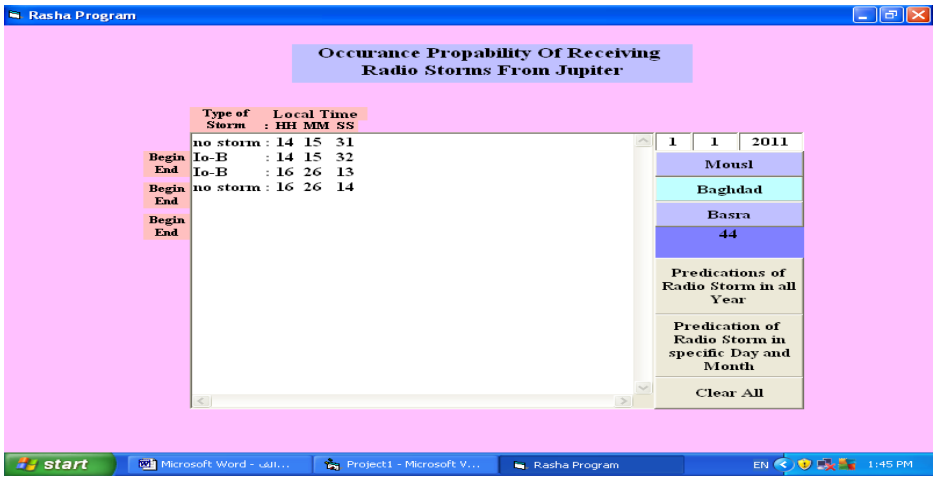


Fig.5: The application window of occurrence of (Io-B) in one day.

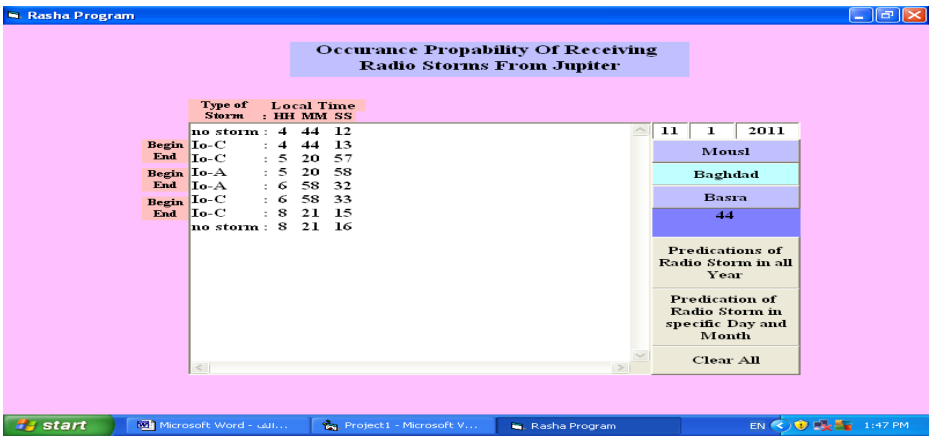


Fig.6: The application window of occurrence of (Io-A) and (Io-C) in one day.

Results:

To predicate the type of the storms that emitted from Jupiter at a specific LT, these ranges are not constant it is change due to the observations by the spacecrafts(**Voyager1 and Voyager2**),

several days from January 2011 is taken for two different Iraqi locations Baghdad, (longitude,44°E) and Basra (longitude,48°E) to show the difference in the LT of receiving each type of storm. According to the ranges of the storms that given in table (1) and (2), which give the observer information about the occurrence probability of each type of storm. Our program give the user facility to predict the type of radio storm not only for these two Iraqi location, but other locations in Iraq and around Iraq, also the user can use any year as he wants to predict the type of radio storms. The flowchart of the program shown in appendix.

The results according to year 1976 were:

- **Iraq, Baghdad, longitude, 44°E.**

Table (3)
Predication of radio storms (year 1976).

Date	*Local Time*		*Type of Storm*
	Begin	*End*	
	HH:MM:SS	*HH:MM:SS*	
4-1-2011	04:34:58	06:12:32	Io-A
4-1-2011	06:12:33	07:21:09	Io-C
5-1-2011	21:14:44	21:54:59	Io-A
5-1-2011	21:55:00	01:50:16	Io-C
6-1-2011	23:18:52	01:29:33	Io-B

Iraq, Basra, longitude, 48°E.

Table (4)
Predication of radio storms (year 1976).

Date	*Local Time*		*Type of Storm*
	Begin	*End*	
	HH:MM:SS	*HH:MM:SS*	
4-1-2011	04:50:58	06:28:32	Io-A
4-1-2011	06:28:33	07:37:09	Io-C
5-1-2011	21:30:44	22:10:59	Io-A
5-1-2011	22:11:00	02:06:16	Io-C
6-1-2011	23:34:52	01:45:33	Io-B

The results according to year 2008 were:

- **Iraq, Baghdad, longitude, 44°E.**

Table (5)
Predication of radio storms (year 2008).

Date	*Local Time*		*Type of Storm*
	Begin	*End*	
	HH:MM:SS	*HH:MM:SS*	
3-1-2011	13:34:18	15:57:02	Io-D
3-1-2011	15:57:03	18:20:58	non-Io-B
3-1-2011	18:22:38	21:06:24	non-Io-A
4-1-2011	03:45:19	07:02:10	Io-A
4-1-2011	07:03:50	08:41:26	non-Io-C
4-1-2011	08:43:06	10:55:26	non-Io-D
4-1-2011	10:55:27	14:12:18	non-Io-B
5-1-2011	14:30:00	16:42:20	non-Io-D
5-1-2011	16:42:21	18:52:50	non-Io-B
6-1-2011	05:56:39	08:40:25	non-Io-A
6-1-2011	08:42:05	10:19:40	non-Io-C
6-1-2011	10:21:20	12:33:40	non-Io-D

Iraq, Basra, longitude, 48°E.

Table (6)
Predication of radio storms (year 2008).

Date	*Local Time*		*Type of Storm*
	Begin	*End*	
	HH:MM:SS	*HH:MM:SS*	
3-1-2011	13:50:18	15:13:02	Io-D
3-1-2011	16:13:03	18:36:58	non-Io-B
3-1-2011	18:38:38	21:22:24	non-Io-A
4-1-2011	04:01:19	07:18:10	Io-A
4-1-2011	07:19:50	08:57:26	non-Io-C
4-1-2011	08:59:06	11:11:26	non-Io-D
4-1-2011	11:11:27	14:28:18	non-Io-B
5-1-2011	14:46:00	16:58:20	non-Io-D
5-1-2011	16:58:21	19:08:50	non-Io-B
6-1-2011	06:12:39	08:56:25	non-Io-A
6-1-2011	08:58:05	10:35:40	non-Io-C
6-1-2011	10:37:20	12:49:40	non-Io-D

Conclusions and Discussion:

1. The program is based on two occurrence of radio storms according to the observations from spacecrafts for several ranges which are chosen in this research for two reasons
   a. To indicate the differences in calculation of the storm occurrence.
   b. To explain that the storm may be occurred or not occurred according to the different ranges taken.
2. The results from this program are given in tables (3,4,5 and 6), these tables for two locations Baghdad and Basra and for two years 1976 and 2008 respectively, it reveals there are no occurrence for any type of storm in some days, while there are one type or more than one type is occurred in other days.
3. The time interval of occurrence Io-A storm in 4^{th} of January 2011 is (04:34:58 to 06:12:32), which gives a predicate observation time of a proximately 2 hours, while the time interval of the same type of the storm in the same day is (03:45:19 to 07:2:10) which gives approximately 4 hours this means the time interval of occurrence Io-A storm in table (5) is longer than the time in table (3), which is much for receiving a storm.
4. The type of the predicate storms are constant for the two locations, but the time interval of occurrence is change due to the longitude of the location, for example in date 4^{th} of January 2011 from table (3) for Baghdad location the (Io-A) is occurred, while the same type of the storm is also occurred for Basra, but the time of occurrence is change, because it depends on the longitude of the location.
5. The time between the two locations (Baghdad and Basra) is constant, for example if the LT of beginning and end of the storm that occurred in the 4^{th} of January 2011 is taken for both Baghdad and Basra respectively (03:45:19 to 07:02:10) and (04:01:19 to 07:18:10), the difference between them is 16 minutes, which is constant for all results.
6. Two different assumptions can accounted for (Earth-Jupiter-Io) geometry:

a. The radiation comes from Jupiter in specific ranges when Jupiter interacts with Io's satellite. From this many types of storms that related and unrelated to the position of Io are seen. This mechanism is responsible for the generation and the escape of this radiation from Jupiter, when different angular sizes or bandwidths are taken for these storms. They are located at large distance from CML of Jupiter and come from the northern hemisphere of the planet. The main and early storms occur near the edge of the plasma torus. A wide range of longitude, perhaps all longitudes, is excited by Io, but the radiation is beamed (either at the emission point or during the propagation) and is received only when the Earth crosses the radiation beam.

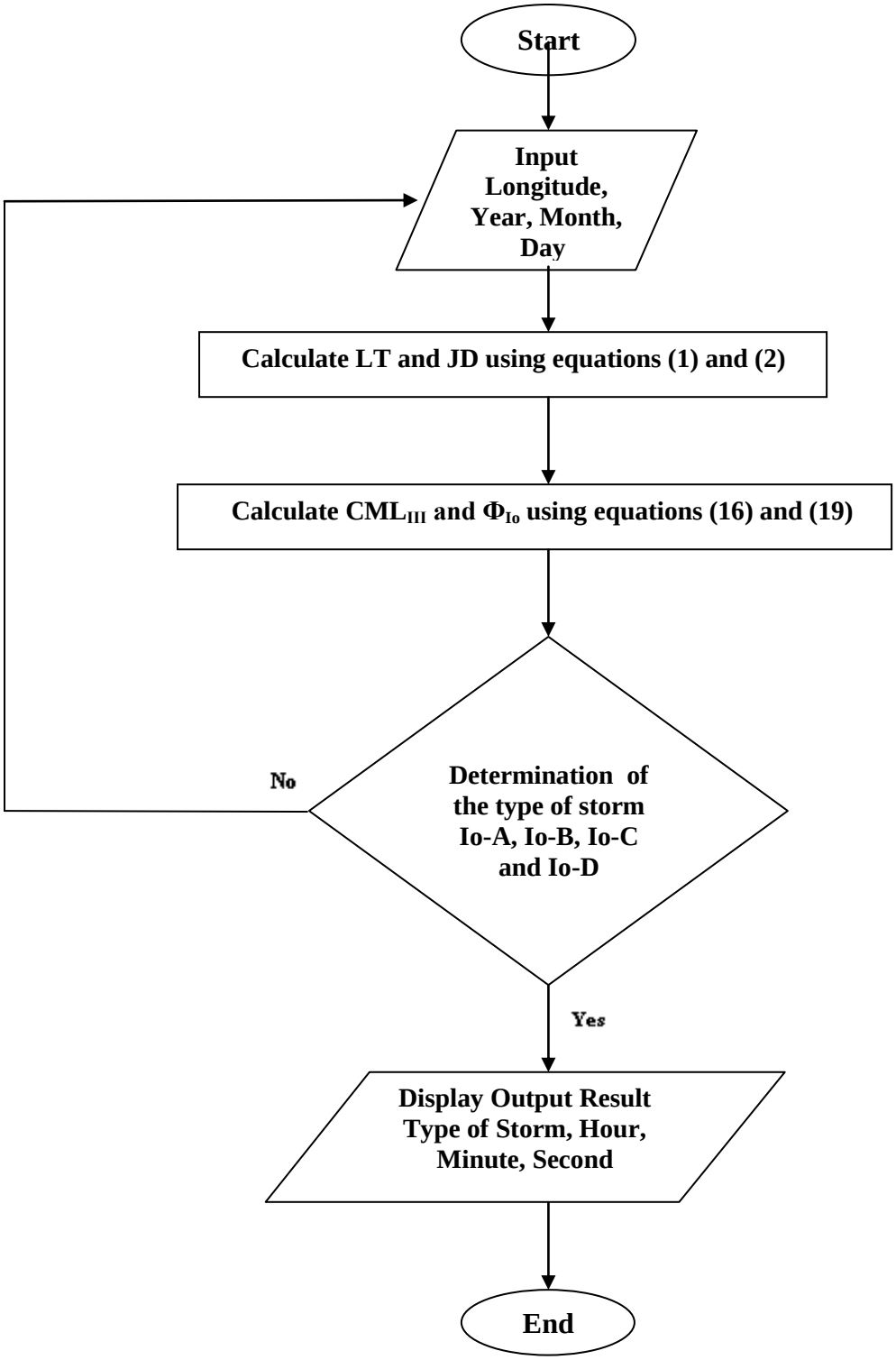
b. The difference in Io Flux Tube (IFT) means variation in plasma torus density and source region. Such variation will affect the orientation of the radiation of the emission as it is generated, or affect the escape of radiation after propagation through the Jovian plasma. These variation are caused by the strength of Io interaction at a certain point along its orbits.

References:

1. John, D. F.,2006, Astronomy Journey to the Cosmic Forntier, 4th edition, MacGraw-Hill, USA,266-275.
2. Jean, M.,1982, Astronomical Formula for Calculators, 4th edition, William-Bell, USA,175-183.
3. Dessler, A. J. and Hill, T. W, 1979, "Jovian Longitudinal Control of Io-Related Radio Emissions", Astrophys. J.,227:664-675.
4. Yi-Jiun, S.,2008,"Electromagnetic Interaction between Jupiter's Ionosphere and the Io Plasma Torus", Proceedings of IAU Symposium Cosmic Magnetic Fields: from Planets, to Stars and Galaxies, held at 3-7 November, Puerto Santiago, Tenerife, Spain,259:1-11.
5. Hess, S., Mottez, F., Zarka, P. and Chust, T.,2007," Generation of the Jovian Radio Decametric Arcs from the Io Flux Tube", J. Geophys. Res.,113(A03209):1-10.
6. Carr, T. D., Desch, M. D. and Alexander, J. K.,1983, Physics of the Jovian Magnetosphere, "Phenomenology of Magnetospheric Radio Emissions", Cambridge University Press, UK, 226-284.
7. Pokorny, Z, 1976"Analysis of Some Properties of Jupiter's Decameter Radiation", Astronomical Institutes of Czechoslovakia, Bulletin,27(3):137-143.
8. Bose, S. K., Sarkar, S. and Bhattacharyya, A. B. ,2008, "Jovian Decametric Radio Emission: An Overview of the Planetary Radio Astronomical Observations", J. Indi. Radio and Space Phys.,37:77-108.
9. Gurntt, D. A. and Goertz, C. K. ,1981," Multiple Alfvén Wave Reflections Excited by Io: Origin of the Jovian Decametric Arcs", J. Geophys. Res.,86(A2):717-722.
10. Michel, F. C.,1979," The Astrophysics of Jupiter", Space Sci. Rev.,24:381-406.
11. Duffet-Smith, P.,1988, Practical Astronomy with your Calculator, 3rd edition, Athenaeum Press Ltd, Great Britain,6-12.

Appendix

The flowchart of the program that calculates the predicted storm (A,B,C and D) at specificLT.



التنبؤ بنوع العاصفة الراديوية من كوكب المشتري من موقعين عراقيين مختلفين

كمال محمد عبود *** ***رشا هاشم ابراهيم*

*قسم الفلك والفضاء، كلية العلوم، جامعة بغداد

الخلاصة:

صمم برنامج بلغة (الفيجوال بيسك) للتنبؤ بنوع العاصفة الراديوية المنبعثة من كوكب المشتري لموقعين في العراق هما بغداد والبصرة وحسب التوقيت المحلي وان مثل هذا النوع من العواصف يأتي من النظام الثالث CML_{III} لكوكب المشتري وطور حركة القمر أيوΦ_{Io}. بعض العواصف يعتمد على موقع القمر أيو (Io-A,B,C,D) و البعض الأخر لا يعتمد على موقعة (non-Io-A,B,C,D) معاملات الإدخال لهذا البرنامج حددت بواسطة المستخدم من خلال موقع الراصد (خط الطول) و السنة والشهر و اليوم). النتائج كانت جداول تجهز المستخدم بمعلومات عن التاريخ والتوقيت المحلي لبداية ونهاية العاصفة المنبعثة. استخدمت سنتين مختلفتين في هذا البرنامج احدها سنة ٢٠٠٨ والأخرى سنة ١٩٧٦، النتائج حسب سنة ٢٠٠٨ أعطت أكثر أنواع من العواصف الراديوية بالمقارنة مع سنة ١٩٧٦وقد أشارت النتائج أن نوع العاصفة لا يتغير لهذة المواقع وإنما التوقيت المحلي الذي ترصد به العاصفة هو الذي يتغير لأنة يعتمد على خط طول الراصد على سطح الأرض. النتائج المستحصلة أوضحت إلى اتفاق جيد عندما قورنت مع نتائج البرنامج العالمي **(Radio Jove)** .